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The Iowa system of soil management

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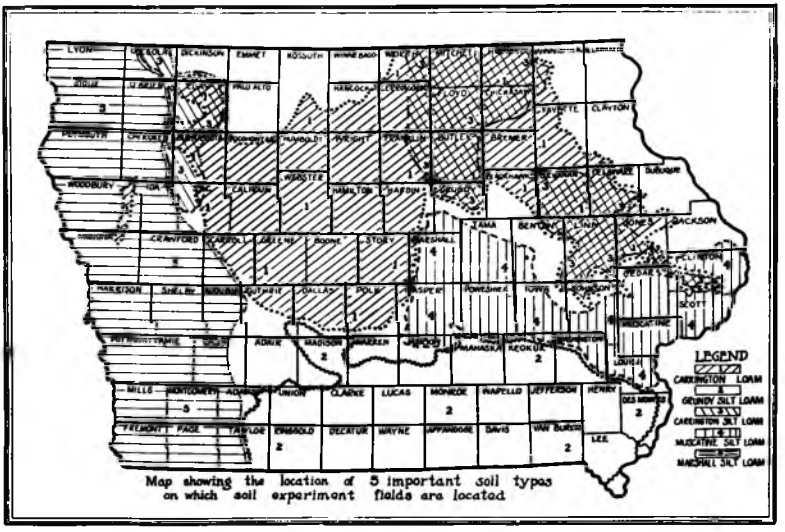
The Iowa System of Soil Management



Map showing the location of 5 important soil types on which soil experiment fields are located

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THE IOWA SYSTEM OF SOIL MANAGEMENT

By W. H. Stevenson and P. E. Brown

Increasing land values have brought Iowa farmers to a realization of the importance of securing larger crop yields *per acre*. This has led to an insistent demand for information regarding soil needs and fertilizer treatments which will make them more profitably productive. The experimental work of the Soils Section of the Iowa Agricultural Experiment Station is planned to meet this demand and to show how larger crops may be grown on the soils of the state. As a direct outcome of this experimental work, the Iowa System of Soil Management has been developed. It is not a complicated, theoretical method of handling soils, but a simple, common sense, practical plan which provides for remedying those soil conditions which limit crop growth and make it impossible to secure the best possible yields.

ALL IOWA SOILS CAN BE MADE MORE PRODUCTIVE

Iowa soils are not unproductive but they may be made to produce larger crops without great difficulty. Experiments have shown that yields may be increased even on the most fertile land in the state if certain methods of soil treatment are followed. These treatments make up the *Iowa system of soil management* and by following them, not only will soils be made more productive, but they may be kept fertile for all time.

The *system* includes only those methods of handling soils which are of proven value. It is sound in theory, but what is more important, it works in practice. The various treatments which are a part of the *system* have been tried out on many farms and have been found profitable. Some of them are well known and quite commonly followed. Occasionally, however, they may be neglected and hence they are included to emphasize their fundamental significance and to insure their being practiced whenever necessary. Certain other treatments suggested are not generally used and their importance is not recognized, but experimental information and farm experience are sufficiently definite now to warrant recommending them.

These recommendations are supported by the results from experiments carried out by the Soils Section and reported in the following pages. The data given were obtained on the cooperative soil experiment fields which are distributed widely over the state, on the most important soil types. The results have been averaged from all the fields on the same soil types and hence they may be considered to show quite definitely the needs of the particular soils wherever they occur and to indicate the value of certain fertilizer applications.

Six of the most extensive soil types of the state are covered in these results: the Marshall silt loam, which covers most of the uplands in western Iowa; the Carrington loam, found on much of the upland in northern and central eastern Iowa; the Muscatine silt loam, extensively developed in the eastern and east central parts of the state; the Tama silt loam, also found in eastern Iowa but chiefly in the central parts of the state; and the Grundy silt loam, the predominating upland soil thruout all southern Iowa.

Farmers on these soils anywhere in Iowa, may be guided by the results secured in these experiments and the suggestions made regarding soil treatments may be carried out with the assurance of beneficial effects on crop yields. The suggestions given here are undoubtedly applicable to all the normal soils in the state as well as to the six types mentioned and hence all Iowa farmers may profit by practicing the treatments and by making the tests which are recommended.

The *Iowa system of soil management,* if put into practice thruout the state, may confidently be expected to bring about larger crop yields and greater profits per acre and to keep the soils of the state permanently fertile.

The treatments which are suggested in this plan of soil management are included under the following headings; each of which will be discussed separately:

1. Drainage and cultivation
2. Manuring and green manuring
3. Liming
4. The use of phosphates and other fertilizers
5. The rotation of crops

DRAINAGE AND CULTIVATION

Probably no other condition essential for successful crop growth is so well known as drainage and yet it is often overlooked. Soils which are too wet will not produce satisfactory crops and no other treatment will bring about any beneficial effects on such soils. Where the conditions are extreme, such as on ponded areas, or on land where water accumulates and stands long after every rainfall, the need for drainage is easily recognized. Many thousands of acres in Iowa have been reclaimed from a condition which absolutely precluded any crop production, by the installation of drainage ditches and tile. Some of the most fertile areas in the state, at the present time, were wet, untillable areas, or even ponds or lakes a few years ago before they were drained.

But there is much land in the state which is still in need of drainage. Many soils are heavy in texture, level in topog-

raphy, or underlaid by a stiff, impervious clay subsoil, and as a result are inadequately drained. The Grundy silty clay loam in southern Iowa, known locally as "gumbo", is a typical example. The Wabash silty clay loam occurring on bottomlands and the Bremer silty clay loam on terraces are other types which are poorly drained for the same reasons. Then there are other soils which have such tough subsoils that they are said to rest on "hard pan" and drainage in such cases is very poor. The so-called "push" soils may also be mentioned as representing a more or less abnormal soil condition which can only be remedied after thoro drainage has been secured. But many areas of normal upland soils, far more extensive in total acreage, are imperfectly drained because of topographic position, texture or subsoil conditions. Crops may do well in dry seasons but in wet years, if not an actual failure, they are often poor and unprofitable. In many cases the soil is slow to warm up in the spring, the crop season is shortened and the yields secured are much lower than they should be.

The installation of tile is usually all that is needed to provide for an adequate removal of excess water. Only where the natural drainage system of an area is poor and outlets for the tile cannot be provided are drainage ditches necessary. With the exception of the northwestern central part of the state, in the Wisconsin drift soil area, where the land is level and streams and natural drainageways are few, there are very few areas where it is difficult to find suitable outlets for tile drains. In most cases streams are quite readily accessible to the tile, and by proper installation thoro drainage may be rather readily accomplished.

The cost of installing tile may be considerable, but the greater value of the crops secured will more than make up for the outlay. It should be emphasized that wherever land is not properly drained, tile should be laid as the first necessary treatment, if large crops are to be secured. Other treatments may then be made with success, but until the area is thoroly drained fertilizing materials will have little or no effect.

The proper cultivation of soil will often prove distinctly effective in increasing crop yields. Frequently plowing is too shallow and the best mechanical soil conditions are not provided for crop growth. By gradually increasing the depth of plowing a better seed bed may be prepared and the soil may be brought into a better state for root development. A larger area is provided for the growth of roots, more food is made available, better air and moisture conditions are maintained in the soil and as a result crop growth may be greatly increased. It is not desirable to change from shallow to deep plowing at one oper-

ation as too much subsoil may be mixed with the surface soil. A gradual change in the depth of plowing, however, often proves very beneficial. In some places where the subsoil is heavy and impervious the "subsoiler" is being used successfully. The deep tillage machine is sometimes employed with beneficial effects, but the cost of this machine is considerable and it can hardly be recommended for general use. Fall plowing is better than spring plowing wherever possible because of the better physical conditions in the soil, better moisture and better plant food production in the spring.

Cultivating the land after plowing is of well-known value. It permits of the preparation of a good seed bed and it makes the soil conditions better for germination and plant growth. Cultivation of tilled crops not only keeps down weed growth but it brings about better moisture and air conditions in the soil and a better production of available plant food. Maintaining a good mulch on the surface soil may have a large effect on crop yields in periods of drought because of the moisture which is conserved.

Emphasis is given in *the Iowa System* to the significance of tiling out wet land and of plowing and cultivating all soils according to the best methods, if the most satisfactory crop yields are to be secured.

MANURING AND GREEN MANURING

The amount of organic matter in a soil, which to some extent determines its fertility, is indicated by its color. Black soils are high in organic matter and usually also in nitrogen, while light colored types are apt to be deficient in both these essential constituents. Hence light colored soils are generally lower in fertility than darker colored types. The importance of organic matter in soils lies in the fact that it contains much plant food, it provides conditions which are necessary for bacteria to make the unavailable plant food constituents of the soil available for use, and it improves the physical condition in soil both for plant growth and for bacterial growth.

If soils are to be made and kept most highly productive, therefore, the organic matter supply must be increased in all light colored, light textured soils and in darker colored types methods must be followed to maintain the supply, owing to the losses which constantly occur. Soils lose organic matter rapidly, when they are cultivated and in light textured, open soils, such as sands and sandy loams, the disappearance is particularly rapid. All Iowa soils, whatever their color or texture must be

treated regularly with some material supplying organic matter if they are to be made most highly productive and kept so.

There are three natural fertilizing materials which may be employed on the farm to supply organic matter to the soil. They are manure, green manures and crop residues. The *Iowa system of soil management* emphasizes the importance of the use of all these materials.

FARM MANURE IS VALUABLE

Farm manure is the best known and most commonly used fertilizing material. It contains much organic matter, considerable amounts of plant food constituents which have been taken from the soil by the growth of the crops used for feed, and it is supplied with large numbers of bacteria and other microorganisms which make plant food available. The addition of farm manure to land, therefore, improves the soil physically, chemically and bacteriologically and the improved soil conditions are reflected in greater crop yields. It is the cheapest and best fertilizing material to use and it brings about large effects on crop yields.

On light soils the effect of manure is most evident, but even on darker colored types, which seem to be well supplied with organic matter, it often has a very beneficial effect. In the latter case the effect of the manure may be due mainly to the bacteria which bring about a production of available plant food, or to improved physical conditions in the soil. In the lighter types, however, the effects are probably due primarily to the organic matter which the manure supplies to the soil. Thus the "life" of the soil is lengthened and the problem of permanent fertility is much simplified. On most normal soils, however, increased crop yields from applications of manure may probably be attributed to a combination of physical, chemical and bacterial effects.

The value of manure from the standpoint of its effect on common farm crops grown on Iowa soils is shown in the tables and figures given later in this bulletin. Averaging the results on the six soil types given in the tables, corn is found to be increased 5.8 bushels per acre; oats, 5.9 bushels; clover, 0.12 ton, by the use of manure. These are average figures from a large number of tests and it should be noted that in many individual cases the increases obtained are much larger and more striking. This is particularly true when the manure is applied to sandy soils and light colored types: such soils, which are of minor occurrence in Iowa, are not included among the types, from which experimental data is reported in this bulletin. Farm manure may be depended upon to give desirable effects on crop growth in practically all cases in Iowa.

MANURE SHOULD BE PROPERLY STORED

Too often the actual value of manure is not appreciated and it is allowed to stand in piles, exposed to the weather and to leaching, thus losing a large part of its valuable constituents. As much as 90 percent of the value of the manure may be wasted when it is handled in this way. It should be carefully stored in covered yards or pits, protected from the weather and kept moist and compact, or it should be hauled out and spread on the land as produced, if it is to bring about the best effects when applied to the soil. It is not always possible to apply manure as produced nor is it always desirable. When storage is necessary some method should be chosen which will permit of the least loss. No one method will serve for all conditions, but any method which keeps it under cover and moist and compact will prove effective. Even if some labor and expense are involved they will be worth while because of greater crop effects.

PROFITABLE APPLICATIONS OF MANURE

The usual application of manure is 8 to 10 tons per acre and rarely is it possible to apply more than this amount to any one field on a farm without leaving some other portion of the farm untreated. It is not often on any livestock farm that the production of manure is sufficient to permit of even this amount being used on all the soils on the farm. In no case, however, is it desirable to apply more than 16 to 20 tons to normal Iowa soils for general farm crops. Applications of about 8 tons per acre give larger increases in crop yields for each ton of manure than is the case when larger amounts are used. Only on light colored, light textured soils are the heavier applications ever more profitable and when soils are very deficient in organic matter it is usually more desirable to use green manure, with a normal amount of farm manure, than to attempt to supply the deficit entirely with farm manure.

On some heavy types of soil, manure should not be applied preceding the small grain crop owing to the danger of causing it to lodge, but a normal application at some other time in the rotation will be desirable even on such types. On newly drained, heavy soils very small amounts of manure often prove extremely beneficial, but large amounts are of course undesirable. When truck crops are grown very large applications may often be made with profit, because of the desirability of forcing a rapid growth, and the greater profit from the crops.

It is much easier to maintain the fertility of the soil on the livestock farm than it is on the grain farm because of the production of manure, and when properly cared for and applied to

the land, the manure produced will save the livestock farmer much expense and difficulty in making his soils more productive and in keeping them fertile.

GREEN MANURING SUPPLEMENTS MANURE

On the grain farm some other material must be employed in place of manure to supply organic matter and on many livestock farms the manure produced will not provide for all the soils, and something must be used to supplement the manure. In both cases, green manuring may often be practiced with very desirable effects.

Green manuring is the growing of a crop and turning it under in the soil. Both legumes and nonlegumes may be employed as green manures but the former are much preferable because of the fact that when well-inoculated, they are able to use the free nitrogen of the atmosphere. Thus, when turned under, there is an increase in the nitrogen content of the soil as well as an addition of organic matter. Non-legumes supply only organic matter and while they may occasionally be employed, there are so many legumes which may be grown under the soil and climatic conditions in Iowa that it is very rarely that they are not preferable.

While green manuring is a necessity on the grain farm and is often necessary also on the livestock farm, it must not be practiced carelessly or blindly or undesirable effects may result. Turning under a heavy green crop, for example, in a dry season, especially in the spring, may injure the moisture conditions in the soil so that beneficial effects will not result from the green manuring and the subsequent crop may suffer because of a lack of necessary moisture.

The clover grown in the rotation often serves as a partial green manure if the first crop is harvested and the second crop plowed under. Better still is the practice of removing only the clover seed, plowing under all the rest of the crop. This can be done if the first crop is clipped and left on the ground and the straw from the hulling machine is spread on the field before the land is plowed. By this method considerable nitrogen and much organic matter may be added to the soil. When clover is cut for hay and removed from the land there is no addition of nitrogen to normal soils and it has no green manuring effect, but when well inoculated it does not remove any nitrogen from the soil and if used for feed and the manure returned to the land beneficial effects may be secured. Other legumes may be grown as catch crops seeded in the corn at the last cultivation or as cover crops and thus serve as green manures.

The return to the soil of all crop residues is a third means by which the organic matter content of the soil may be maintained. They also add some plant food constituents but they are chiefly of value in keeping up the organic matter supply. On the live-stock farm the straw, stover and other residues may be used for feed or bedding and returned to the soil in the manure. On the grain farm the straw may be allowed to decompose partially before application and the corn stalks and stubble may be plowed under but in both systems of farming these residues should never be burned or otherwise destroyed, as so often happens because of a lack of appreciation of their value.

The *Iowa system* of managing soils provides for the careful preservation and application to soils of all the manure produced on the farm, for the proper use of leguminous crops as green manures as substitutes for or supplements to farm manure and for the return to the soil of all crop residues.

LIMING

Crop production is never as satisfactory on acid soils as on soils properly supplied with lime. Practically all crops grow best where lime is present and legumes frequently refuse to grow at all where the soil is acid. The small grain crops and corn are not so sensitive to acidity, but they are indirectly affected, for in acid soils there is not a proper production of available plant food and crops may not be properly supplied. The experimental results given later in this bulletin show beneficial effects from liming six important Iowa soils, not only on the legume in the rotation, but also on the general farm crops grown.

MANY IOWA SOILS ARE ACID

Many Iowa soils are acid and in need of lime. Soils in the northeast central, eastern and southern parts of the state are quite generally lacking in lime and the soils in the western and northwest central parts of the state are gradually becoming acid in the surface soils. For the best crop production in Iowa, therefore, it is necessary that all the soils of the state be tested for acidity and lime requirement and that the proper application of lime be made. The farmer may test his own soils or he may send a small sample or in fact any number of samples to the Soils Section of the Iowa Agricultural Experiment Station and have tests made free of charge. The actual amount of lime to be applied must be determined for each individual soil as there is great variation in lime requirement. It is always advisable to test the soil in each field separately and thus determine the proper amount of lime to use on the particular area.

Limestone is most generally applied in Iowa to correct soil acidity as it is cheaper and more readily obtained than other forms of lime. It may be secured at various places in the state, sometimes as a product, direct from the quarry, and sometimes as a waste product. The limestone available in the state varies somewhat in composition and the higher grade materials are of course the most desirable. Information regarding the composition of the limestone from various Iowa quarries may be secured from the Soils Section of the Iowa Agricultural Experiment Station and samples may be submitted to be tested where there is doubt as to the purity of the material. Low grade limestone must be applied in very much larger amounts to bring about the same effects and the cost of transportation and application is much increased.

It is important also that the material be in a finely divided condition if the effect on the soil is to be the most desirable and from general experience it seems that it should consist of at least 60 percent dust. Sources from which limestone may be secured in the state are given in Circular No. 82 of the Iowa Agricultural Experiment Station.

MUCH PROOF THAT LIMING PAYS

Many experiments in Iowa and much farm experience have shown the value of applying lime to acid soils. Farmers have frequently been unable to grow alfalfa at all on their land until they applied lime and similar experiences have been reported with other legumes. Thus increases due to lime in the case of legumes vary from 0.17 tons of hay up to the entire crop produced. With other crops, however, surprising increases are often secured. Averages from the results of all the tests on the six soil types reported in this bulletin show a 3.8 bushel increase for corn and 3.1 bushel gain for oats. In individual cases much larger increases than these are secured. Farm experience in general confirms the conclusion that liming is of very definite value on many soils in the state.

The cost of liming is quite variable and depends chiefly on the distance from the quarry. Freight costs are heavy and add much to the expense. Limestone itself may usually be secured at about $0.75 per ton f. o. b. the quarry. If it can be obtained nearby, the total cost of application therefore is not high. The beneficial effects are so definite, however, that the expense involved is usually well warranted by the increases in crops secured by its use.

The reasons for the value of lime are that it supplies plant food, it neutralizes acidity produced by the decomposition processes going on in soils and it makes the soil conditions better

for the growth of the bacteria which are responsible for the production of available plant food. It also improves the physical condition of many soils, opening up heavy, tight soils and making them better aerated and tightening up loose, open soils, permitting them to hold moisture better. The beneficial effects on corn and oats are probably very often due, at least in part, to the fact that the clover crop of the rotation has been increased and the greater clover residues have a beneficial effect on the following crops.

Tht *Iowa system of soil management* recognizes the necessity of liming acid soils and it includes therefore the recommendation that all soils be tested for acidity and lime requirements and that lime be applied as needed. Furthermore one application will not be sufficient for all time, as lime is lost rather rapidly from soils, by leaching and in other ways, and it is urged that soils be tested at least once in the rotation, preferably preceding the clover or other legume crop and that lime be applied regularly as needed. Only in this way will it be possible to secure the best crop yields and to keep up the fertility of the soils indefinitely.

THE USE OF PHOSPHATES AND OTHER FERTILIZERS

Analyses have shown that most Iowa soils are low in content of total phosphorus and it might be expected, therefore, that they would respond to phosphorus fertilization. The field experimental work carried out by the Soils Section has included tests of the value of phosphorus on some of the most important soil types in the state. The results from these tests on six soil types are averaged in the tables and figures given in the following pages.

There are several phosphorus fertilizers which may be employed, two of these, namely rock phosphate and acid phosphate, which are most generally used, are employed in all the above experiments under the livestock system of farming with manure and lime and under the grain system with crop residues and lime. Rock phosphate is slowly available and must be used in large amounts but it costs less, while acid phosphate is readily available, and is applied in small amounts, having however a higher cost per unit of phosphorus.

In all these experiments rock phosphate was added at the rate of 2,000 pounds per acre once in a four-year rotation while acid phosphate was applied at the rate of 200 pounds annually. The former was plowed under in the fall while the acid phosphate was applied in the spring. In the livestock system plots, manure was added at the rate of 8 tons per acre once in a four

year rotation while in the grain system all crop residues were utilized. Lime was applied in both systems in amounts necessary to neutralize the acidity and supply two tons additional.

In addition to the two phosphates, tests were included of the value of a complete commercial fertilizer. Originally the old standard 2-8-2 brand was employed, but in the more recent tests the newer standard 2-12-2 brand has been used. The 2-8-2 complete fertilizer was applied at the rate of 300 pounds per acre annually in the spring. Since the 2-12-2 brand has been employed, 267 pounds have been used, thus giving an equivalent amount of phosphorus to that supplied in the 200 pounds of 16 percent acid phosphate.

These plot experiments were all laid out on land which is thoroly representative of the particular soil type. Fertilizer applications were carefully made and crop yields were secured with all precautions that the results should be accurate. The plots were located in various counties thruout the state on farms, whose owners cooperate in the work. All were laid out on fields where a definite rotation was practiced.

It is intended to carry all these experiments over a period of years in order to make the results more definite but the average results given in the tables are obtained from many yields on a large number of fields and hence they may be considered quite definitely indicative of the needs of the particular soil types which are represented. Some interesting conclusions may be drawn from them which will show what part phosphorus plays in the Iowa System of Soil Management.

RESULTS ON THE CARRINGTON LOAM

On the Carrington loam (table I, chart 1) manure brought about a very definite crop increase in the case of the corn and the oats and a small increase in the clover. Lime in addition to manure increased the yields of the three crops still further, having less effect, however, than the manure on the corn and oats but more on the clover. The rock phosphate and acid phosphate had very similar effects on the corn; the rock showed up slightly better on the oats but the acid phosphate proved more effective on the clover. The complete commercial fertilizer gave similar increases to the phosphate on all three crops, showing no superior effects. It would be less profitable therefore because of the greater cost.

On the crop residue plots, the residues showed some effect and lime gave increases for all three crops. The rock phosphate and acid phosphate also increased the yields of the three crops, the acid phosphate having a somewhat greater effect than the rock in all cases. The differences, however, were not large. The

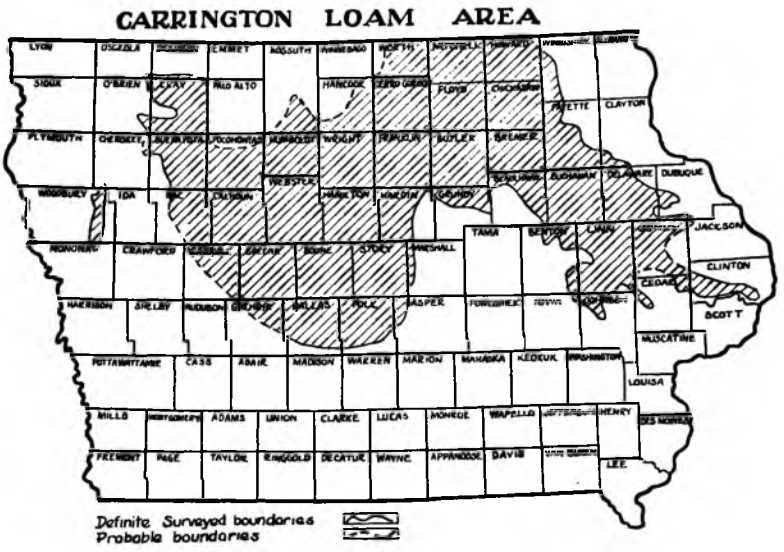

Fig. 1—Map showing the location and boundary of Carrington loam area.

TABLE I. CARRINGTON LOAM
Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover	
	Av. Yield bu. per acre	Increase for treatment, bu. per acre	Av. yield bu. per acre	Increase for treatment, bu. per acre	Av. yield, tons per acre	Increase for treatment, tons per acre
Check	51.9	....	43.6	....	1.25	....
Manure	58.8	6.9	49.6	6.0	1.38	0.13
Manure+Lime	62.6	10.7	53.0	9.4	1.57	0.32
Manure+Lime+Rock phosphate	66.0	14.1	62.3	18.7	1.97	0.72
Manure+Lime+Acid phosphate	66.3	14.4	60.8	17.2	2.27	1.02
Manure+Lime+Complete commercial fertilizer	66.8	14.9	62.4	18.8	2.29	1.04
Crop residues	54.7	2.8	47.3	3.7	1.37	0.12
Crop residues+Lime	57.5	5.6	49.3	5.7	1.41	0.16
Crop residues—Lime+Rock phosphate	61.8	9.9	51.2	7.6	1.80	0.55
Crop residues+Lime+Acid phate	62.4	10.5	52.7	9.1	1.94	0.69
Crop residues+Lime+Complete commercial fertilizer	64.2	12.3	58.2	14.6	2.02	0.77

*Corn yields averaged from 20 crops on 10 fields, oats from 9 crops on 5 fields and clover from 15 crops on 9 fields.

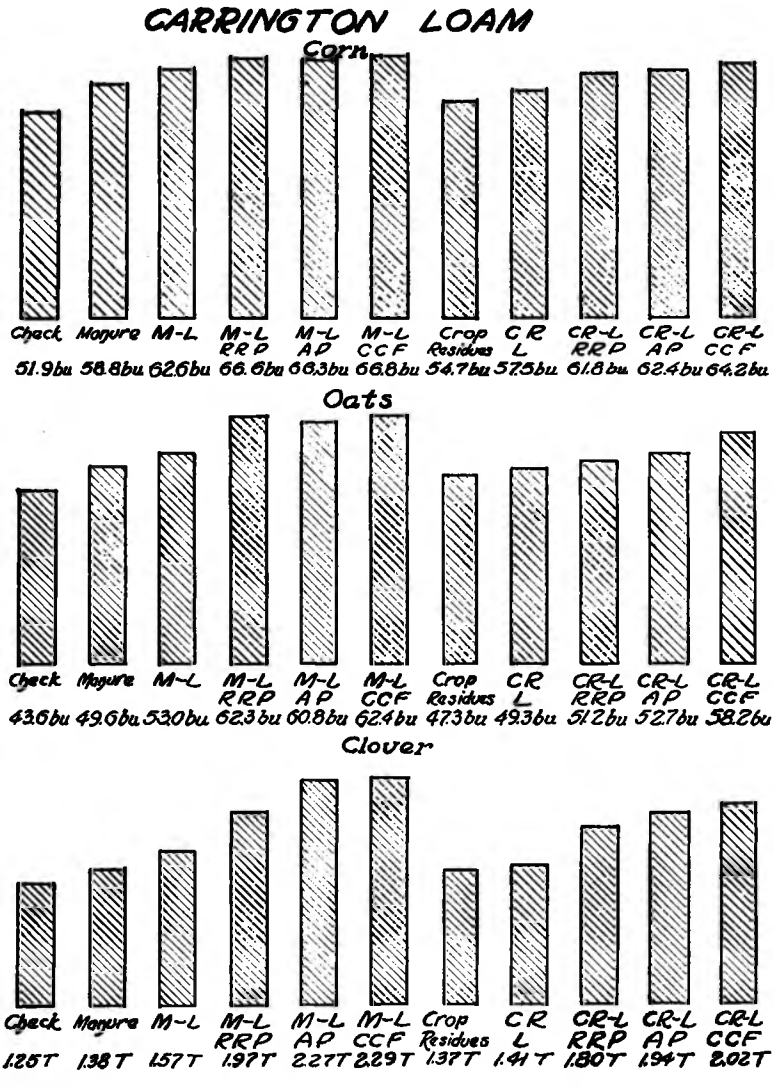

Chart 1—These columns show the different yields of crops secured by different soil treatments on Carrington loam.

complete commercial fertilizer proved somewhat more beneficial than the phosphates but not enough to pay for its greater cost.

Apparently on the Carrington loam, yields of corn, oats and clover may be increased by the application, of manure, lime and phosphorus. Lime gave the most effect on the clover as would be expected. Rock phosphate and acid phosphate had similar effects, the acid phosphate proving somewhat superior both with manure and with crop residues. The complete commercial fertilizer did not produce effects which were enough greater than those brought about by the phosphates to warrant its use.

RESULTS ON THE GRUNDY SILT LOAM

The results of the Grundy silt loam (table II, chart 2) show very definite increases for manure on corn, oats, clover and wheat. Lime with manure increased all the crops showing quite as pronounced effects on the corn, oats and wheat as on the clover. The phosphates both brought about larger crop yields but the acid phosphate proved superior to the rock in all cases, being particularly more effective in the case of the clover. The complete commercial fertilizer showed less influence in all cases than the acid phosphate but somewhat greater effect than the rock, except in the case of the wheat.

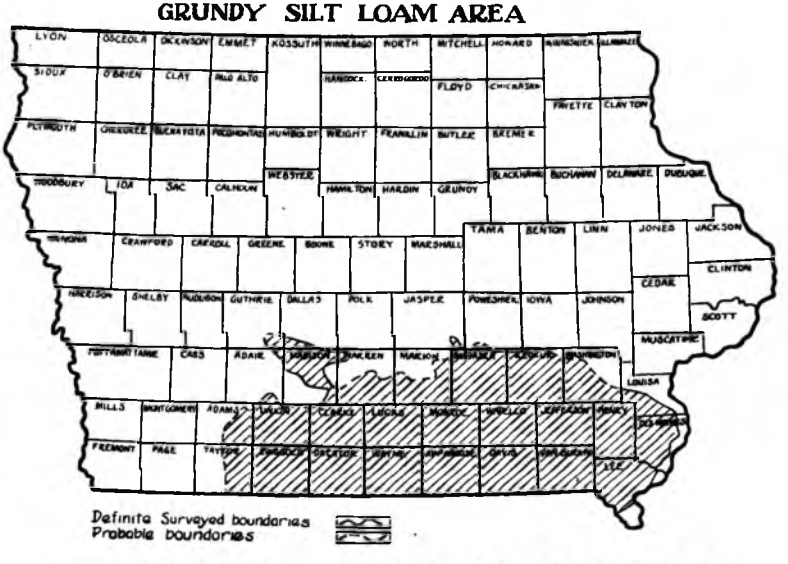

Fig. 2—Map showing the location and boundary of Grundy silt loam.

ERRATA

TABLE II, PAGE 305—GRUNDY SILT LOAM

CHECK YIELDS SHOULD BE AS FOLLOWS:

Corn —56.9 bu.
Oats —45.6 bu.
Clover—1.98 tons
Wheat—22.4 bu.

CLOVER YIELD ON MANURE PLOT SHOULD BE 2.14 tons

TABLE III, PAGE 307—MARSHALL SILT LOAM

YIELDS ON MANURE TREATED PLOTS SHOULD BE AS FOLLOWS:

Corn	*—63.4 bu.*	*Increase 5.0 bu.*
Oats	*—42.3 bu.*	*Increase 6.5 bu.*
Clover--	*1.4 tons.*	*Increase 0.07 tons*
Wheat—	*15.5 bu.*	*Increase 0.2 bu.*

TABLE II. GRUNDY SILT LOAM

Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*		Winter wheat*	
	Bu. per acre	Increase from treatment, bu. per acre	Bu. per acre	Increase from treatment, bu. per acre	Tons per acre	Increase from treatment, tons per acre	Bu. per acre	Increase from treatment, bu. per acre
Check	58.4	....	35.8	....	1.33	....	15.3	....
Manure	62.9	6.0	49.6	4.0	1.14	0.16	29.2	6.8
Manure + Lime	67.3	10.4	56.6	10.0	2.34	0.36	32.5	10.1
Manure + Lime + Rock phosphate	69.0	12.1	60.2	14.6	2.65	0.67	34.2	11.8
Manure + Lime + Acid phosphate	72.7	15.8	64.9	19.3	2.86	0.88	34.7	12.3
Manure + Lime + Complete commercial fertiliber	69.2	12.3	61.7	16.1	2.83	0.85	33.1	10.7
Crop residues	60.3	3.4	51.6	6.0	2.23	0.25	25.1	2.5
Crop residues + Lime	61.9	5.0	53.3	7.7	2.33	0.35	....	....
Crop residues + Lime + Rock phosphate	63.0	6.1	61.5	15.9	2.62	0.64	28.8	6.4
Crop residues + Lime + Acid phosphate	64.8	7.9	59.3	13.7	2.65	0.67	28.9	6.5
Crop residues + Lime + Complete commercial fertilizer	65.8	8.9	56.9	11.3	2.62	0.64	28.3	5.9

*Corn yields averaged from 11 crops on 9 fields; oats from 6 crops on 4 fields; clover from 10 crops on 8 fields; and wheat from 3 crops on 3 fields.

The crop residues brought about small effects on all the crops. Lime with the residues showed small but definite increases and the phosphates both produced larger yields of all the crops, there being very little difference in the effects of the two materials. The complete commercial fertilizer showed up slightly better than the phosphates on the corn but was not superior on the other crops.

These results show that the Grundy silt loam will respond to applications of manure, lime and phosphorus, acid phosphate proving somewhat better than rock, when used with manure and lime. The complete commercial fertilizer was apparently not as desirable for use as the phosphates.

RESULTS ON THE MARSHALL SILT LOAM

The data secured on the Marshall silt loam are given in table III and chart 3. The value of manure on corn, oats, clover and wheat on this soil is clearly shown, the effects being the greatest on the corn and oats. Lime increased the yields of all the crops, particularly the clover and wheat. The phosphates with manure and lime gave distinct increases in all cases but the acid phosphate was superior to the rock in every instance, the difference being the greatest in the case of the clover. The complete commercial fertilizer had less effect than the phosphates on the corn, clover and wheat but gave somewhat greater

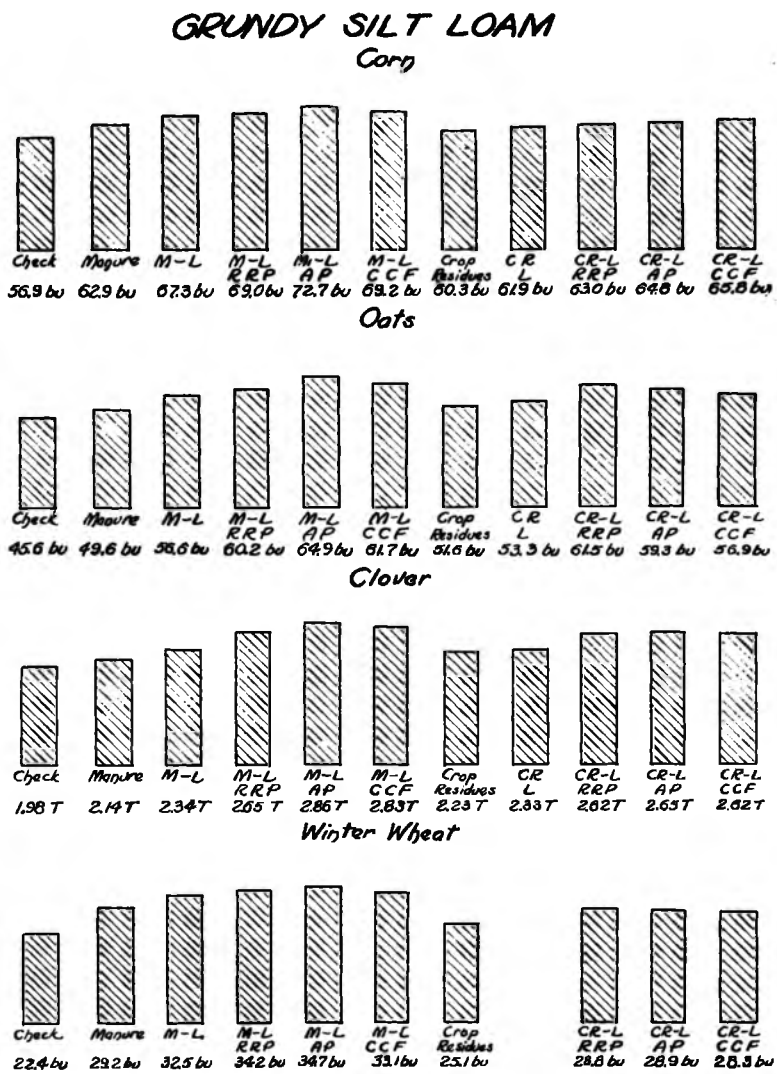

Chart 2—These columns show the different yields of crops secured by different soil treatments on Grundy silt loam.

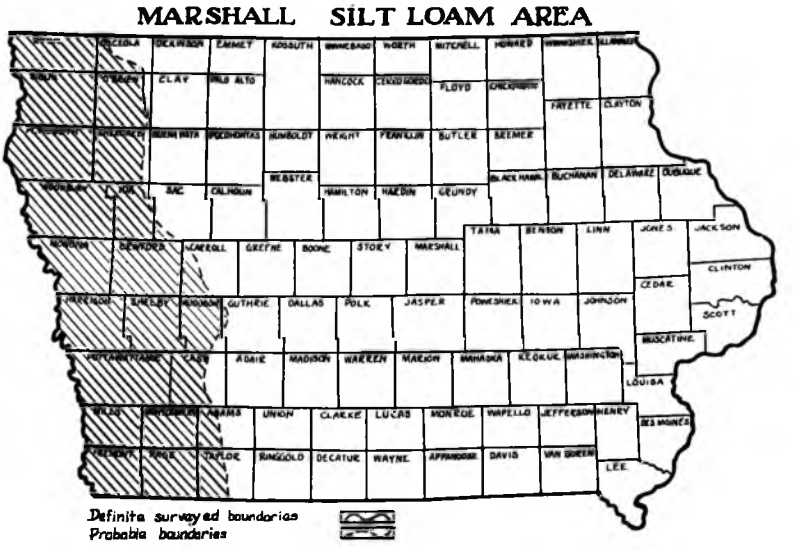

Fig. 3—Map showing the location and boundary of Marshall silt loam area.

TABLE III. MARSHALL SILT LOAM
Average Crop Yields and Increases Due to Fertilizer Treatment Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*		Winter wheat*	
	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, tons per acre	Increase for treatment, tons per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre
Check	58.4	....	35.8	....	1.33	....	15.3	....
Manure	67.2	8.8	47.8	12.0	2.70	1.38	23.8	8.5
Manure+Lime	65.7	7.3	44.4	8.6	1.60	0.27	18.6	3.3
Manure+Lime+Rock phosphate	70.2	11.8	45.8	10.0	2.80	1.47	28.6	13.3
Manure+Lime+Acid phosphate	71.6	13.2	48.8	13.0	3.40	2.07	30.7	15.4
Manure+Lime+Complete commercial fertilizer	69.4	11.0	52.0	16.2	2.60	1.27	25.4	10.1
Crop residues	59.3	0.9	43.5	7.7	1.50	0.17	16.4	1.1
Crop residues+Lime	63.0	4.6	43.8	8.0	2.20	0.87	19.5	4.2
Crop residues+Lime+Rock phosphate	67.2	8.8	47.8	12.0	2.70	1.37	23.8	8.5
Crop residues+Lime+Acid phosphate	67.5	9.1	52.0	16.2	2.80	1.47	22.3	7.0
Crop residues+Lime+Complete commercial fertilizer	64.9	6.5	50.8	15.0	2.70	1.37	22.2	6.9

***Corn yields averaged from 4 crops on 4 fields; oats from 4 crops on 4 fields; clover from 1 crop on 1 field and winter wheat from 1 years results on 1 field.**

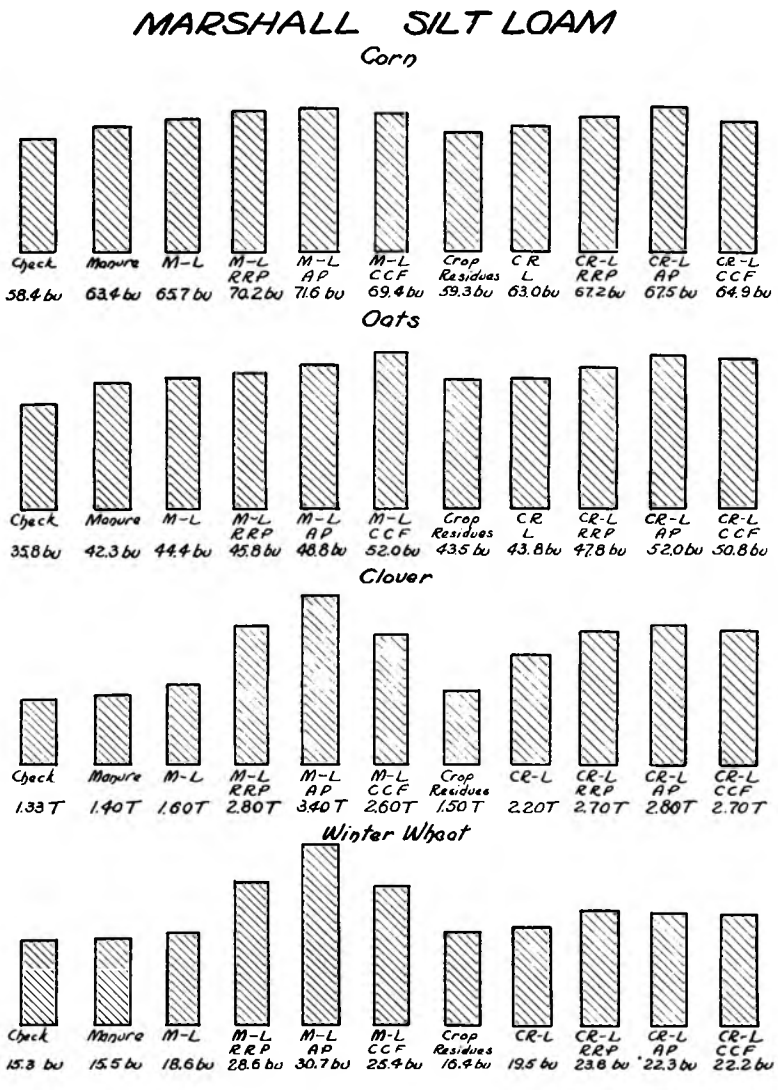

Chart 3—These columns show the different yields of crops secured by different soil treatments on Marshall silt loam.

effects on the oats, not enough however to make its use profitable.

The crop residues showed slight effects on all the crops. Lime with the residues gave pronounced increases. The phosphates both had beneficial effects, but the acid phosphate proved more effective particularly on the oats. The complete commercial fertilizer showed less effect than the acid phosphate in all cases and only with the oats was it better than the rock.

The Marshall silt loam may evidently be profitably fertilized with manure, lime and phosphorus, acid phosphate proving somewhat better than the rock both in the livestock system of farming with manure, and in the grain system with crop residues. The complete commercial fertilizer had less effect than the acid phosphate in practically all cases and cannot be considered as desirable for use on this soil. Lime is evidently of value on this type when it is acid but as the soil is often basic in reaction lime should not be applied until tests have shown it to be needed.

RESULTS ON THE MUSCATINE SILT LOAM

On the Muscatine silt loam, as shown in table IV, chart 4, manure brought about considerable increases in all the crops. Lime in addition to manure showed gains in practically all

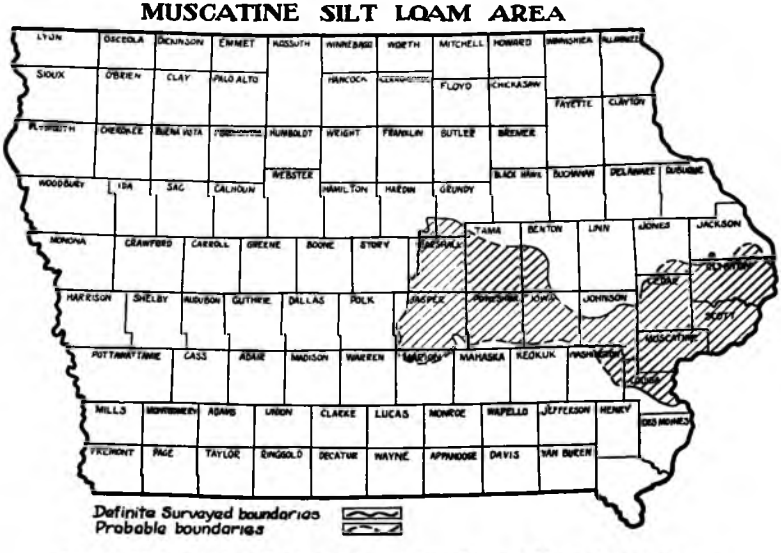

Fig. 4—Map showing the location and boundary of Muscatine silt loam.

TABLE IV. MUSCATINE SILT LOAM

Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*		Winter wheat*	
	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, tons per acre	Increase for treatment, tons per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre
Check	64.4	....	54.0	....	2.39	....	17.8	....
Manure	68.5	4.1	58.6	4.6	2.53	0.14	20.6	2.8
Manure + Lime	73.8	9.4	58.6	4.6	2.62	0.23	23.9	6.1
Manure + Lime + Rock phosphate	76.1	11.7	62.6	8.6	2.83	0.44	28.5	10.7
Manure + Lime + Acid phosphate	73.7	9.3	62.6	8.6	2.88	0.49	27.5	9.7
Manure + Lime + Complete commercial fertilizer	73.4	9.0	67.4	13.4	2.83	0.44	31.2	13.4
Crop residues	66.6	2.2	56.4	2.4	....	....	20.6	2.8
Crop residues + Lime	66.9	2.5	....	....	2.59	0.20	19.6	1.8
Crop residues + Lime + Rock phosphate	72.6	8.2	67.4	13.4	2.62	0.23	23.9	6.1
Crop residues + Lime + Acid phosphate	71.1	6.7	....	....	2.71	0.32	24.3	6.5
Crop residues + Lime + Complete commercial fertilizer	69.2	4.8	69.4	15.4	2.73	0.34	22.5	4.7

*Corn yields averaged from 5 crops on 4 fields, oats from 1 crop on one field, clover from 2 crops on one field and winter wheat from 1 crop on one field.

cases, the effects being especially noticeable on the corn, no gains appearing with the oats. The rock phosphate and acid phosphate showed practically identical increases except in the case of the corn where the acid phosphate had practically no effect. The complete commercial fertilizer showed superior effects over the phosphates on oats and wheat but had less effect on the corn and clover. In no cases were the increases sufficient to warrant its use.

Crop residues gave slight effects as usual and lime showed some influence on the clover but not on the other crops. The phosphates had similar effects, the acid phosphate proving somewhat better on the clover and wheat, while the rock was slightly better on the corn and oats. The oats results are for one year only and hence they cannot be considered very definite. The complete commercial fertilizer had less effect than the phosphates on the corn and wheat but was somewhat more beneficial on the oats and clover, not enough however to make its use desirable.

The results of these tests on the Muscatine silt loam indicate quite definitely that this soil may be treated with manure, lime and a phosphorus fertilizer with satisfactory results. Both with manure and with crop residues, lime and the phosphates brought about crop increases, acid phosphate showing up somewhat bet-

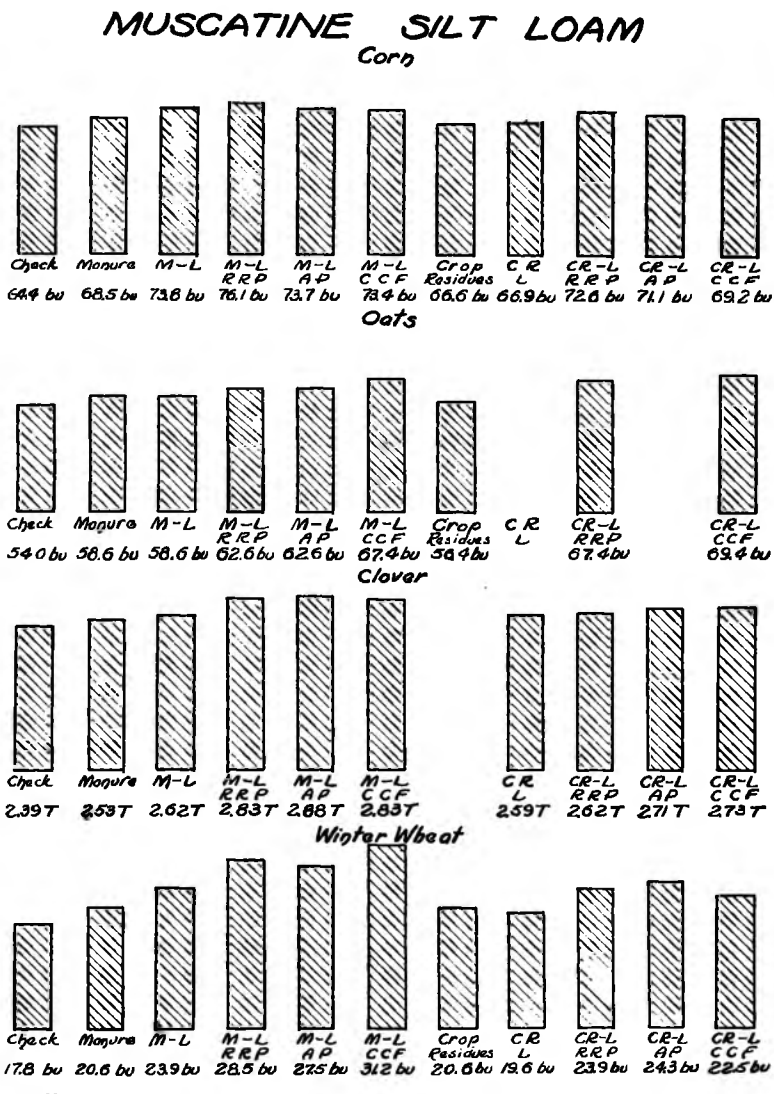

Chart 4—These columns show the different yields of crops secured by different soil treatments on Muscatine silt loam.

ter on the clover and small grains while the rock had about the same or a slightly greater effect on the corn. The complete commercial fertilizer generally produced less effect than the acid phosphate and hence the latter would seem to be a preferable material for use.

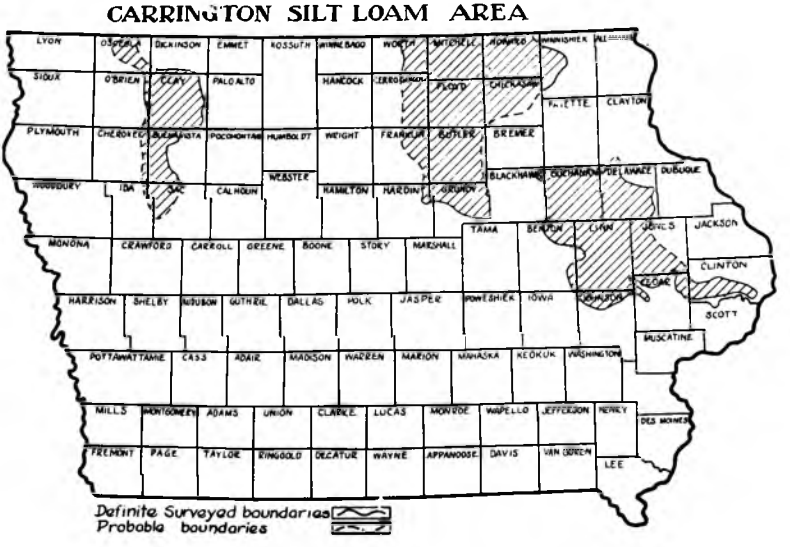

Fig. 5—Map showing the location and boundary of Carrington silt loam area.

TABLE V. CARRINGTON SILT LOAM

Average Crop Yields and Increases Due to Fertilizer Treatment Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*	
	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, tons per acre	Increase for treatment, tons per acre
Check	59.2	....	49.2	....	1.28	....
Manure	65.9	6.7	60.3	11.1	1.38	0.10
Manure + Lime	71.4	12.2	56.3	7.1	1.55	0.27
Manure + Lime + Rock phosphate	74.6	15.4	61.2	12.0	2.00	0.72
Manure + Lime + Acid phosphate	74.5	15.3	61.2	12.0	2.25	0.97
Manure + Lime + Complete commercial fertilizer	74.3	15.1	67.3	18.1	2.16	0.88
Crop residues	60.0	0.8	55.0	5.8	1.36	0.08
Crop residues + Lime	65.1	5.9	50.3	1.1	1.48	0.20
Crop residues + Lime + Rock phosphate	63.5	4.3	61.8	12.6	1.89	0.61
Crop residues + Lime + Acid phosphate	65.0	5.8	59.8	10.6	2.00	0.72
Crop residues + Lime + Complete commercial fertilizer	69.7	10.5	67.3	18.1	1.95	0.67

*Corn yields averaged from 6 crops on 2 fields, oats from 1 crop on 1 field and clover from 3 crops on 2 fields.

RESULTS ON THE CARRINGTON SILT LOAM

The results on the Carrington silt loam are given in table V, chart 5, and as on the other types manure gave large increases in the various crops. The effect was noted particularly on the

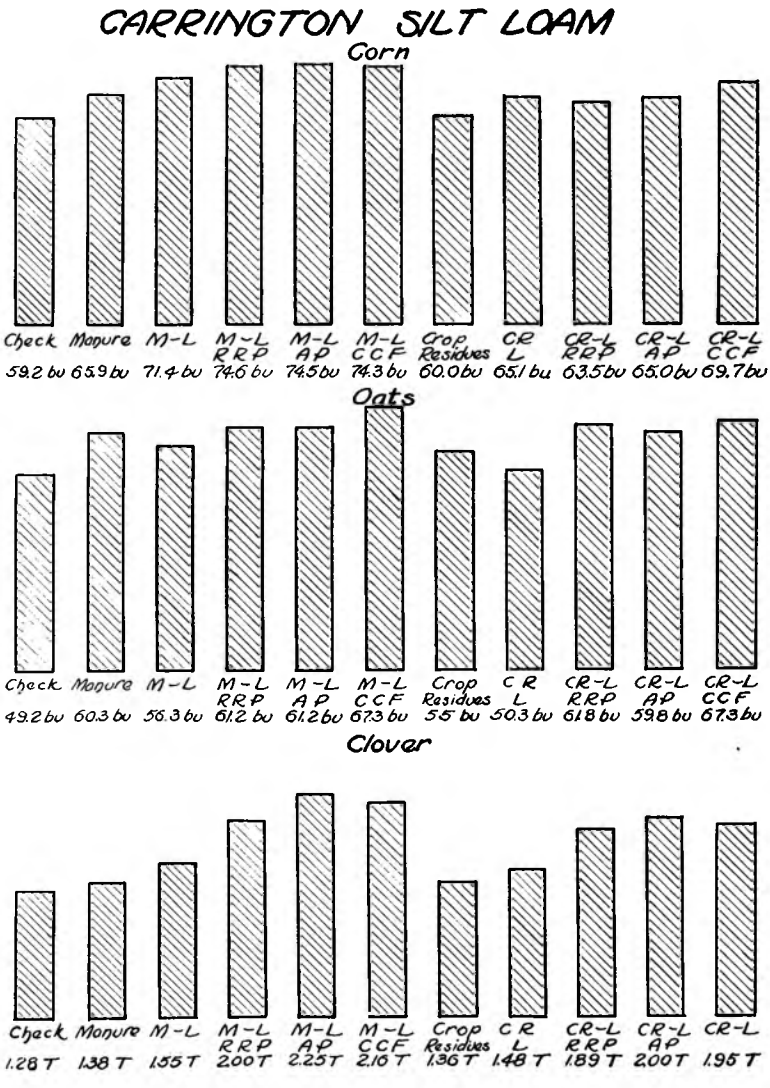

Chart 5—These columns show the different yields of crops secured by different soil treatments on Carrington silt loam.

oats. Lime with manure gave increases in corn and clover but not in oats. The clover increase was very definite. The phosphates showed practically identical effects on the corn and oats but the acid phosphate proved superior on the clover. The complete commercial fertilizer had more effect on the oats than the phosphates but proved less effective on the clover than the acid phosphate.

The crop residues had little effect on the crop yields. Lime again showed profitable increases on the clover and corn but not on the oats. Only one year's results with oats are given here and hence the results should not be considered definite with this crop. The phosphates increased the various crops, acid phosphate giving slightly larger gains in the clover and corn than the rock. The complete commercial fertilizer showed greater effects on the corn and oats than the phosphates but the differences would not warrant the greater expense of the application.

The value of manure, lime and phosphorus on the Carrington silt loam is evidenced in these results. Acid phosphate seemed somewhat preferable to rock on the clover crop, both in the live-stock and in the grain systems of farming. With the other crops however, there seems very little choice. The complete commercial fertilizer did not produce effects enough greater than those brought about by the phosphates to warrant its use.

RESULTS ON THE TAMA SILT LOAM

The effects of the various treatments on corn and oats on the Tama silt loam are given in table VI, chart 6. Manure showed its usual effect on crop yields on this soil and lime with manure gave further definite increases. The phosphates had very similar effects on both crops, the rock being a little better in both cases. The complete commercial fertilizer was more effective on the oats than the phosphates but had less influence on the corn. The increase with the oats, however, was not large. Crop residues showed some effect and lime again gave distinct increases. The phosphates with crop residues and lime produced definite effects, the acid showing up better than the rock on both crops. The complete commercial fertilizer had greater effects on the oats but less on the corn.

This soil type responds very much like the Carrington silt loam to fertilizer treatments. Manure was of large value, lime additions were profitable and showed definite effects on corn and small grains, and phosphates were of value. The rock and acid phosphates seemed to have very similar effects, the acid showing up somewhat better in the absence of manure but the rock gave slightly greater effects when used with manure. Not

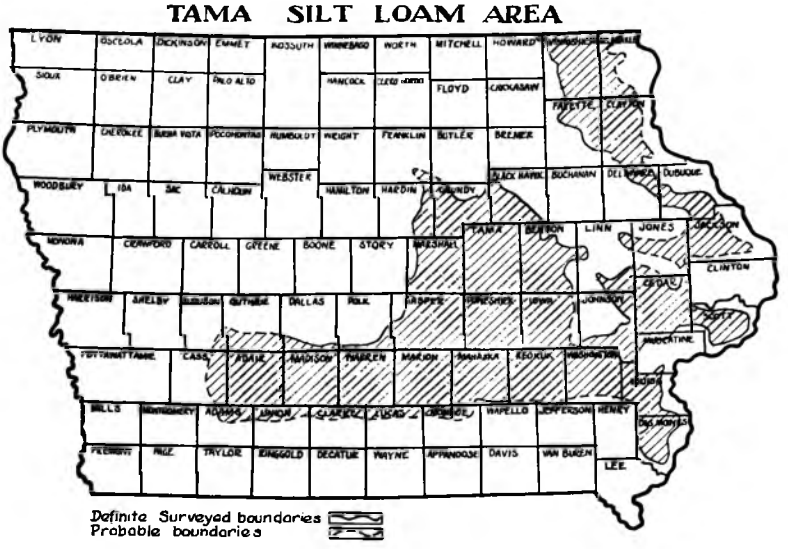

Fig. 6—Map showing the location and boundary of Tama silt loam area.

as many results are available on this soil as in the other cases and hence the conclusions are not so definite. Both phosphorus carriers may be recommended for use on this soil and results on individual farms may help in deciding which material to use in any particular case. The complete commercial fertilizer, as in other cases, did not give large enough increases to warrant its application.

TABLE VI. TAMA SILT LOAM

Average Crop Yields and Increases Due to Fertilizer Treatment Iowa Experiment Fields

Treatment	Corn*		Oats*	
	Bu. per acre	Increase from treatment, bu. per acre	Bu. per acre	Increase from treatment, bu. per acre
Check	63.2	....	46.0	....
Manure	69.6	6.3	49.4	3.4
Manure+Lime	71.8	8.5	56.3	10.3
Manure+Lime+Rock phosphate	77.7	14.4	58.6	12.6
Manure+Lime+Acid phosphate	75.3	12.0	56.7	10.7
Manure+Lime+Complete commercial fertilizer	73.7	10.4	62.9	16.9
Crop residues	69.7	6.4	47.0	1.0
Crop residues+Lime	71.8	8.5	57.9	11.9
Crop residues+Lime+Rock phosphate	74.4	11.1	58.9	12.9
Crop residues+Lime+Acid phosphate	75.7	12.4	63.3	17.3
Crop residues+Lime+Complete commercial fertilizer	72.7	9.4	68.0	22.0

*The corn yields are the averages of 3 crops on 2 fields. The oats yields are the averages of 2 crops on 2 fields.

The value to be derived from the application of phosphorus fertilizers to Iowa soils is quite definitely shown in the data just discussed. The indications from the results are that acid phosphate will frequently prove preferable to rock phosphate, at least on the soil types on which the tests were carried out. In other cases, on other types, possibly the rock might be more profitable. Farmers may test the two materials on their own soils by simple tests which are described in Circular 82 of the Iowa Agricultural Experiment Station. The conclusion seems well warranted however that many Iowa soils will respond profitably to phosphorus fertilization.

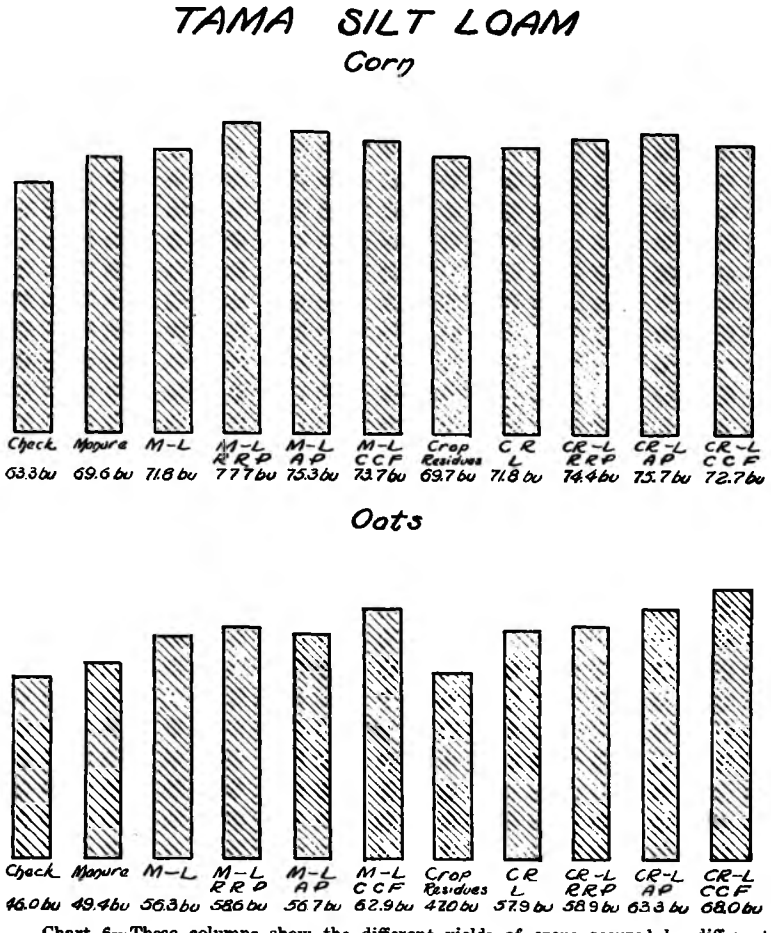

Chart 6—These columns show the different yields of crops secured by different soil treatment on Tama silt loam.

Complete commercial fertilizers containing nitrogen, phosphorus, and potassium do not seem to be as desirable for use on Iowa soils as phosphates. They cost more and the effects are often smaller. Apparently the nitrogen and potassium which they contain are of little value and the additional cost therefore is not warranted. Acid phosphate seems quite as satisfactory and more profitable on these soils studied and similar results would probably be secured for general farm crops on many other types. Complete commercial fertilizers may be tested on individual farms, if desired, however, and if results show them to be of superior value to acid phosphate they may be used. Their cost should be compared with the value of the increase in the crops if the results are to be calculated economically. There is no objection to the use of these materials if they prove profitable, particularly if they are more profitable than acid phosphate with which they should always be compared.

The use of commercial nitrogen and potassium fertilizers is not generally necessary on Iowa soils. Small amounts of these materials may be used as top dressings, but for general farm crops, legumes are the cheapest nitrogenous materials which can be used and there seems to be abundant potassium present in most Iowa soils to keep crops supplied. Potassium fertilizers are being tested in some field experiments now under way and it may be found that it will be desirable to apply some soluble potassium in the form of the muriate or the sulfate to certain soils even tho they are well supplied with total potassium. Results from these experiments are not yet available and will be reported later.

For truck crops certain brands of complete commercial fertilizers are very desirable and very profitable and the results for general farm crops given above should not be considered to apply to truck crops. Special fertilization is necessary in such cases for forcing the early growth of the crops and special brands of fertilizers either complete or incomplete are quite generally used.

THE ROTATION OF CROPS

The proper rotation of crops is absolutely essential to continued successful crop production. One crop grown continuously on land will very quickly reduce its fertility, due to various undesirable effects on the soil and often to the production of diseased conditions in the crop. A good rotation will prove more profitable over a period of years than the continued growing of even a money crop like corn, as has been shown by much experimental work.

Many rotations are practiced with desirable results and no

rotation can be said to be the best for all conditions. Almost any rotation is desirable, provided it contains a legume and the money crops. The necessity for the presence of the legume lies in the fact that the leguminous residues are of considerable value in keeping up the nitrogen and organic matter in the soil. The common rotation in Iowa is corn, corn, oats and clover. Often the rotation is corn, oats, clover and wheat. A shorter rotation of corn, oats and clover is desirable if it is desired to build up the soil. A longer rotation with alfalfa is sometimes employed, the alfalfa being kept on the land five years. Sometimes the three year rotation is lengthened to four by growing clover and timothy two years. The second year the crop will consist mainly of timothy. Various other modifications of these rotations are followed successfully in some instances.

The *Iowa system of soil management* includes the rotation of crops as a factor of great importance in the proper production of crops and in the keeping of the soils in a permanently productive condition.

CONCLUSION

The importance of securing greater crop yields and of keeping up production on Iowa land calls for the adoption of a more or less definite system of treatment. The *Iowa system of soil management* has been developed from much experimental work and from extensive study and farm experience and it is evident now that by proper drainage and cultivation, manuring and green-manuring, liming, the use of phosphates and other fertilizers and the rotation of crops, Iowa soils may be made more productive and kept so. The Iowa system of managing soils is logical and it works. It is up to the Iowa farmers now to put it into effect and to derive the benefits which may come from its adoption and use.

In some cases applications of lime or phosphates may not prove profitable for a period of a few years after their first use. As a rule no farmer should reach a final decision as to their value until he has carried his tests thru at least one complete rotation. If after a careful test covering four or five years any fertilizer proves to be unprofitable, of course its continued use is not recommended. But many Iowa farmers should undoubtedly test the value of lime and phosphates on their own farms, for the experimental evidence submitted in this bulletin indicates that profitable effects may generally be secured.